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Age estimates of *Sporolithon durum* (Corallinales, Rhodophyta) from Rottnest Island, Western Australia, based on radiocarbon-dating methods

Nisse A Goldberg[1,2] & John N Heine[3,2]

[1] School of Plant Biology, University of Western Australia, Crawley, WA 6009, Australia
[2] Present address: Department of Biology and Marine Science, Jacksonville University, Jacksonville, FL 32211, USA
[3] CSIRO Marine and Atmospheric Research, Floreat, WA 6014, Australia

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Abstract

Rhodoliths are free-living coralline algae, found along the coastal waters of temperate and tropical Australia. However, species diversity of rhodoliths has not been investigated to the extent of other subtidal macrophytes. Due to their slow growth rates and longevity, rhodoliths can be aged using radiocarbon dating methods. We aimed to identify species diversity and ages of living rhodoliths collected from Rottnest Island, Western Australia. Rhodoliths were collected from beneath the seagrass canopy of *Posidonia* spp. and *Amphibolis antarctica* from Nancy Cove in average depths of 2 m. Rhodolith diversity consisted only of *Sporolithon durum* (Corallinales, Rhodophyta). Radiocarbon dates from three rhodoliths were estimated using Accelerator Mass Spectrometry. Estimated ages were post-1950, regardless of whether the age was estimated from within 5 mm or up to 15 mm from beneath the rhodolith surface. Age estimates contrast with living rhodoliths collected from deeper waters (depths of 38 m) off the southern coast of Western Australia, whose oldest age estimate was from the year AD 1050. We suggest that seagrass meadows may help facilitate the persistence and growth of rhodoliths growing in the clear and shallow waters of Rottnest Island.

Keywords: rhodoliths, Australia, radiocarbon-dating, encrusting coralline algae

Introduction

Rhodoliths or maerl are found worldwide with records from polar and tropical waters (Foster 2001). Rhodoliths are free-living coralline algae growing subtidally in soft sediments. When they blanket the seafloor, rhodoliths increase habitat complexity by providing hard substratum for recruitment of sessile organisms and interstitial spaces for motile animals. Individual rhodoliths may be represented by a single species or an assemblage of species (Foster 2001). Taxa of rhodoliths found in Australian waters include *Lithophyllum, Lithoporella, Lithothamnion, Hydrolithon munitum, Sporolithon,* and Melobesiodeae (a *Mesophyllum* or *Synarthrophyton*) (Collins 1988, Sim & Townsend, 1999, Goldberg 2006). Net growth of a rhodolith can result in an increase in rhodolith diameter and/or increase in frond length. Net growth may be uninterrupted resulting in long-lived individuals, or be interrupted due to periods of sediment burial (Littler *et al.* 1991, Goldberg 2006). Growth rates can be relatively slow with a minimum of < 0.01 mm/yr and a maximum of 2.7 mm/yr, depending on the species and physical factors such as water depth (Foster 2001).

In Western Australia, living rhodoliths have been recorded in warm and temperate waters: from the western coast in the Houtman Abrolhos Islands and along the Rottnest Shelf (Collins 1988), and along the southern coast in the Recherche Archipelago (Goldberg 2006). In addition, rhodoliths have been recorded from four locations along the coast of Rottnest Island (Playford 1988, Kendrick & Brearley 1997, Sim & Townsend 1999). We aimed to collect and identify living rhodoliths growing in the shallow-waters of Rottnest Island; estimate the ages of living rhodoliths using Accelerator Mass Spectrometry; and compare species diversity and ages from our collections to published records of rhodoliths located in deeper waters along the southern coast of Western Australia (Goldberg 2006).

Materials and Methods

Living rhodoliths were collected from Nancy Cove, Rottnest Island (32°02'S, 115°28'W) in average depths of 2 m, in October 2006. Rottnest Island is located off the western coast of Western Australia, in the Indian Ocean. Local marine communities are influenced by the southerly-flowing Leeuwin Current, oligotrophic conditions, microtidal changes in seawater levels (< 1.5 m range), and exposure to onshore wind flow and southern ocean swells (Collins 1988, Playford 1988). The island was separated from the mainland of Western Australia about 6500 years ago, is part of a chain of limestone islands and reefs, and is about 10.5 km long and 4.5 km wide (in Playford 1988). Nancy Cove and Green Island are situated along the middle of the south-facing coast of the island, and are protected from the prevailing southerly winds and swell by offshore limestone reefs (Sim & Townsend 1999). Green Island is about 75 m from shore.

Rhodolith collections were made between Green Island and the shores of Nancy Cove. Species identifications were made from these rhodolith samples. In addition, we purposely collected 3 large (73, 78, 87 mm in diameter) rhodoliths in order to age each individual along a cross-section (Fig. 1). Subtidal vegetative assemblages associated with the rhodolith bed consisted of turf algae, encrusting coralline algae, and the seagrasses *Posidonia* spp. and *Amphibolis antarctica*.

Radiocarbon ages of three individual rhodoliths were estimated using Accelerator Mass Spectrometry (AMS) at the Australian National Tandem Accelerator for Applied Research facility at the Australian Nuclear Science and Technology Organization (ANTSO). Rhodoliths were pink and assumed to have been alive at the time of collection. Dried rhodoliths were first cut in half using a water-lubricated diamond saw. Approximately 20 mg was drilled from within 0–5 mm and 5–10 mm of the outer surface along the cut face. Non-algal material was carefully avoided. For two rhodoliths, an additional sample was collected 10–15 mm from the outer surface. Samples were prepared for AMS ^{14}C analysis as described in Hua *et al.* (2001): rhodolith samples were converted to carbon dioxide and then to graphite. The AMS ^{14}C results were calibrated with the marine calibration curve (Hughen *et al.* 2004), and corrected for $\delta\ ^{13}C$ isotopic fractionation and local oceanic reservoir (reservoir correction: 323 ± 86 years; approximate ΔR value of 25 ± 1 pMC; Gillespie & Polach 1979, V. Levchenko, ANTSO, pers. comm.).

Results and Discussion

The rhodolith bed from Nancy Cove, Rottnest Island, consisted of rhodoliths interspersed among seagrass blades in average depths of 2 m (Fig. 2). Individual fragments in the rubble were approximately 10–20 mm in length, and larger individuals ranged in diameter from 70 to 220 mm. Kendrick & Brearley (1997) had reported spherical rhodoliths at Nancy Cove with diameters of 100 mm. In our collections, rhodoliths had nuclei of coralline algae and overall morphology was ellipsoidal to spherical.

Rhodoliths consisted of one species, *Sporolithon durum* (Foslie) R.A. Townsend & Woelkerling, from our collections. In Australia, *Sporolithon durum* (Sporolithaceae, Corallinales, Rhodophyta) has been reported from Western Australia (Rottnest Island), New South Wales (Byron Bay, Coffs Harbour, Jervis Bay, Twofold Bay, Port Stephens, Botany Bay), and in Victoria (Gabo Island) (Woelkerling 1996, Harvey *et al.* 2002). At Rottnest Island, Sim & Townsend (1999) identified rhodoliths of *S. durum* from depths of 2 to 36 m. In even deeper waters (< 60 m) at the Rottnest Shelf, rhodoliths consisting of the genus *Lithothamnion* had been recorded (Collins 1988).

Species diversity of coralline algae that made up individual rhodoliths differed between the shallow-water (depths of 2 m) bed sampled in our study and the deeper-water (depths of 35 m) bed sampled in Esperance Bay, Western Australia (Goldberg 2006). Species richness of rhodoliths growing in Esperance Bay consisted of approximately four taxa, including the possibility of a *Sporolithon* species (Goldberg 2006). By comparison, only *S. durum* was identified in our study and that of Sim & Townsend (1999) in the shallow waters of Rottnest Island.

Surprisingly, samples were modern (1950 to present) regardless of whether the section was sampled 0–5 mm or up to 15 mm in from the surface of the rhodolith (Table 1). Resolution was limited by the radiocarbon methodology used in this study. Ages could not be discerned beyond a timeframe of 1950 (bomb pulse) to present given that percent carbon was greater than 100 pMC (Table 1, pers. comm. V. Levchenko, ANTSO). In contrast to the relatively young and larger (>70 mm in diameter) rhodoliths collected from Rottnest Island, age estimates of much smaller rhodoliths (55 mm maximum diameter) from Esperance Bay were significantly older with a maximum age estimate of AD1050 as measured from 9 mm beneath the rhodolith's surface (Goldberg 2006). We recommend using staining methods to measure growth rates of *S. durum* from Rottnest Island in order to better estimate ages of the shallow-water rhodoliths (Foster 2001).

In Nancy Cove, rhodoliths were found interspersed within a seagrass meadow (Fig. 2). We suggest that seagrasses may facilitate the persistence of rhodoliths growing in shallow and non-turbid waters. Seagrass meadows stabilize sediments and can serve as a baffle to attenuate wave energy (Piller & Rasser 1996), thereby minimizing the potential for burial of rhodoliths (Steller & Foster 1995). The ellipsoidal shapes of rhodoliths from Nancy Cove were similar to those collected from a bed in the Red Sea, Egypt with a comparable physical habitat (depths of 1 to 3 m, exposure to a microtidal climate, protection from wave energy by adjacent reefs, presence of a seagrass meadow) (Piller & Rasser 1996). Insufficient water motion may prevent rolling of larger rhodoliths (lower surface was paler pink compared to the upper surface) as suggested by Piller & Rasser (1996) (but see Steller & Foster 1995).

Despite the year-round presence of a seagrass canopy, the leaves may not inhibit recruitment of coralline algae. Sim & Townsend (1999) had recorded successful recruitment of coralline algae under a kelp canopy in

Table 1

Age estimates from three living rhodoliths that were collected from depths of 2 m at Rottnest Island, Western Australia.

ANTSO* code	Rhodolith individual (maximum diameter)	Distance (mm) from rhodolith surface	$\Delta(^{13}C)$ per mil graphite	Conventional ^{14}C age (month and year + 1σ error)
OZJ346	1 (78 mm)	0–5	-0.8	1950 to present
OZJ347	1	5–10	-1.7	1950 to present
OZJ348	2 (73 mm)	0–5	-0.7	1950 to present
OZJ349	2	5–10	-1.3	1950 to present
OZJ350	2	10–15	0.9	1950 to present
OZJ351	3 (87 mm)	0–5	-1.0	1950 to present
OZJ352	3	5–10	-2.0	1950 to present
OZJ353	3	10–15	-0.8	1950 to present

*ANTSO: Australian Nuclear Science and Technology Organisation

Figure 1. *Sporolithon durum* rhodolith (ANTSO code OZJ351-353 from Table 1).

Figure 2. Rhodoliths in seagrass meadow.

Nancy Cove. Instead, seagrass blades may minimize the potential of overexposure to irradiance by *S. durum*, which had also been recorded in depths of 36 m (Sim & Townsend 1999). Thus, seagrasses may facilitate the existence and persistence of rhodoliths in shallow-waters.

The persistence of rhodolith beds in Nancy Cove may rely upon vegetative fragmentation of rhodoliths and settlement of propagules from *S. durum* populations (Sim & Townsend 1999). Rhodolith rubble (diameters < 10 mm) may represent a substratum for spores or gametes to settle and grow. Investigations of rhodolith growth rates, reproductive potential, individual survivorship, and fate of fragments may help clarify processes that contribute to the persistence of the Nancy Cove rhodolith bed.

In summary, living rhodoliths collected in shallow waters from Rottnest Island were species depauperate and young compared to deep-water rhodoliths collected from the south coast of Western Australia. The rhodoliths from Rottnest Island were interspersed under a seagrass canopy. The seagrass meadow may help minimize the effects of solar inhibition (*i.e.* possible photodamage) and wave action (burial and excessive fragmentation). The presence of rhodoliths in the seagrass meadow may also increase local productivity and diversity due to increased microhabitats for a variety of macroscopic and microscopic flora and fauna.

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